Summary Report

For

Kentucky Commercial Vehicle Safety Applications Evaluation

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On the cover: (Top right) Laurel County, Kentucky, deployment of advanced Integrated Safety and Security Enforcement System. (Center) Simpson County, Kentucky, deployment.

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Abbreviations

Abbreviation	Definition
ALPR	Automated license plate recognition
CMV	Commercial motor vehicle
CV	Commercial vehicle
CVISN	Commercial Vehicle Information Systems and Networks
CVSA	Commercial Vehicle Safety Applications (Kentucky)
DHS	U.S. Department of Homeland Security
DVR	Digital video recorder
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration (USDOT)
FMCSA	Federal Motor Carrier Safety Administration (USDOT)
FMCSR	Federal Motor Carrier Safety Regulations
IIS	Intelligent Imaging Systems
IR	Infrared
ISS	Inspection Selection System
ISSES	Integrated Safety and Security Enforcement System
ITS	Intelligent transportation systems
JPO	Joint Program Office (USDOT)
KTC	Kentucky Transportation Center (Univ. of Kentucky)
KVE	Kentucky Vehicle Enforcement
LTCCS	Large Truck Crash Causation Study
MCMIS	Motor Carrier Management Information System
MDI	Model Deployment Initiative
NAFTA	North American Free Trade Agreement
OCR	Optical character recognition
OOS	Out of service
ORNL	Oak Ridge National Laboratory
RE	Roadside enforcement
RITA	Research and Innovative Technology Administration (USDOT)
SAFER	Safety and Fitness Electronic Record
SM	Safe Miles
TFSS	Truck Fleet Safety Survey
USDOT	US Department of Transportation
VMT	Vehicle miles traveled
VNTSC	John A. Volpe National Transportation Systems Center (USDOT)
WIM	Weigh in motion

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Introduction

An advanced-technology Integrated Safety and Security Enforcement System (ISSES), now deployed at three commercial vehicle inspection sites along interstate highways in Kentucky, was evaluated from the point of view of system performance, potential effects on inspection selection efficiency (choosing the highest-risk trucks from the stream of commerce), user acceptance, and costs. The deployment was part of the Kentucky Commercial Vehicle Safety Applications (CVSA) program.

Highlights of the results include the following:

- The KVE inspectors at the Laurel County (London) Interstate 75 northbound weigh/inspection station were not using the ISSES to any great extent during the period of the field study. According to interviews with inspectors and with staff from the KTC, the ISSES hardware was functioning satisfactorily, but the state's current enforcement staffing levels—and an organizational emphasis on the quantity of inspections completed, as opposed to the rate of OOS orders issued—prevent inspectors from having the time or incentives to make effective use of the information being displayed by the ISSES.

- Although they were not yet integrated with any state or national data sources, the portions of the ISSES under evaluation in this study appeared to be performing as designed.

- The system has the potential to reduce commercial vehicle related crashes, injuries, and fatalities substantially if deployed more widely and if connected with current and historical sources of safety and inspection data.

- The users at the Laurel site were positive toward the ISSES and appeared to recognize its potential, but regarded it as more of a developmental test or research device than as a tool that they wanted to use immediately in their day-to-day commercial vehicle inspection and law enforcement duties.

Details of the results with supporting methods, analysis, and data are presented in a separate technical report (USDOT 2008).

Background on Deployment and Evaluation

The London, Kentucky, northbound weigh station on Interstate 75 is the site of an advanced, computer-aided, integrated system intended to help commercial vehicle inspectors with

Kentucky Vehicle Enforcement (KVE) improve the effectiveness and efficiency of roadside safety, security, and registration enforcement operations. The system, which was commissioned in June 2005 and formally dedicated by the Governor on August 12, 2005, is now in daily operation (Figures 1 and 2).

Officials in Kentucky refer to the system as the Integrated Safety and Security Enforcement System (ISSES).[1] The system is also known as part of "Kentucky's Weigh Station of the 21st Century." The station is located at mile marker 33 between Corbin and London in Laurel County. Funded in part by the Kentucky Transportation Cabinet through federal highway funds (Project VII.H.15.C), the system is the first of its kind in the country. Since 2005, two similar systems have been installed in

- Kenton County (I-75 southbound at mile marker 168, 20 miles south of Cincinnati/Covington, commissioned August 2006)

- Simpson County (I-65 northbound at mile marker 4, on the route from Nashville, Tennessee, commissioned October 2006).

The Kenton and Simpson county sites are shown in Figures 3 and 4, respectively. A fourth site, in Lyon County (I-24 eastbound in southwestern Kentucky), is also being considered for 2008.

Partners with the Kentucky Transportation Cabinet in this deployment include KVE, the University of Kentucky Transportation Center (KTC), and the Federal Motor Carrier Safety Administration (FMCSA, an agency of the US Department of Transportation, or USDOT). The KTC is working with Transportation Security Technologies LLC (TransTech, based in Oak Ridge, Tennessee)—which is the vendor leading a consortium of private-sector equipment developers and manufacturers—plus various other component vendors, suppliers, software developers, subcontractors, and system integrators to undertake the Kentucky deployment. A list of contact persons from each organization is presented in Appendix A.

The focus of the present evaluation is commercial vehicle safety and enforcement, in particular assessing the capability of the ISSES to provide inspectors with real-time inspection-decision aids. The system also, however, has homeland security applications in terms of detection and prevention of radiological incidents or attacks. These security functions are outside the scope of this FMCSA-sponsored evaluation.

[1] Three of the abbreviations used in this report happen to be similar and may be confusing. "ISSES" stands for the advanced-technology portal screening system deployed in 2005 and being evaluated at Laurel County. "ISS" is the USDOT computer-based Inspection Selection System, introduced in 1995, and available nationally to aid in the commercial vehicle inspection decision process. "IIS" is the corporate abbreviation for Intelligent Imaging Systems, a private company formerly known as Thermal Eye Technologies, which is active as a vendor in the development and deployment of the ISSES.

Figure 1. London, Kentucky, northbound I-75 weigh station (Laurel County). ISSES thermal inspection cameras in foreground and portal monitor/automated vehicle identification system in background.

Figure 2. London, Kentucky, ISSES deployment. System control cabinet at left; elevated radiation detection panels close to truck lane on either side; visible lighting and identification camera apparatus in foreground.

Figure 3. Kenton County ISSES site.

Figure 4. Simpson County ISSES site.

The USDOT sponsored an independent evaluation of the Kentucky deployment, to provide the government with important information on the accuracy, applicability, feasibility, and measurable benefits of selected technologies for use in other jurisdictions that may be considering similar Intelligent Transportation System (ITS) deployments. The independent evaluation, which is described in this report, is known as the Commercial Vehicle Safety Applications (CVSA) Evaluation. An Evaluation Strategy (USDOT 2005a), Evaluation Plan (USDOT 2006c), and Test Plan (USDOT 2007c) were prepared, detailing the research objectives, hypotheses, evaluation measures, and data collection and analysis methods. This evaluation is organized around three related studies:

- System performance
- Inspection efficiency, with a focus on safety improvements
- User acceptance and costs.

A Technical Report on the independent evaluation, providing further detail, analysis methods, and supporting data, was also prepared (USDOT 2008). The purpose of this Summary Report is to highlight the results, benefits, and lessons learned from the Kentucky CVSA Evaluation.

Goals of the ISSES Deployment Project

The overall goal of the roadside deployment at the London northbound station is to enhance the screening of commercial trucks by more readily identifying those trucks that might pose safety hazards and/or unreasonable risks to homeland security. Kentucky seeks to develop a roadside system that gives the inspectors automated tools to work more efficiently, while not burdening the inspectors with added duties and complexity. Notifications from the system should be backed up by valid, accessible, and convenient data at the roadside.

Technologies Being Deployed

The ISSES technology in Kentucky is intended to give inspectors real-time information about trucks passing by the scale house at a slow ramp speed through several integrated subsystems:

- A bulk radiation detection monitor
- A front tractor automated license plate recognition (ALPR) system
- A USDOT number reader, using optical character recognition (OCR) technology
- A thermal imaging (infrared, or IR) inspection system
- A vehicle classification system (laser scanner).

The system also includes an overview (color still image) camera mounted near the roof of the scale house and a (visible) color video image system in parallel with the IR camera. The Kentucky deployment of ISSES is unique in that it is attempting to integrate disparate enforcement and security functions. The locations of the primary systems relative to the overall weigh station layout in Laurel County are illustrated in Figure 5. A KVE inspector using the inspection shed to measure the brake stroke on a commercial truck is shown in Figure 6.

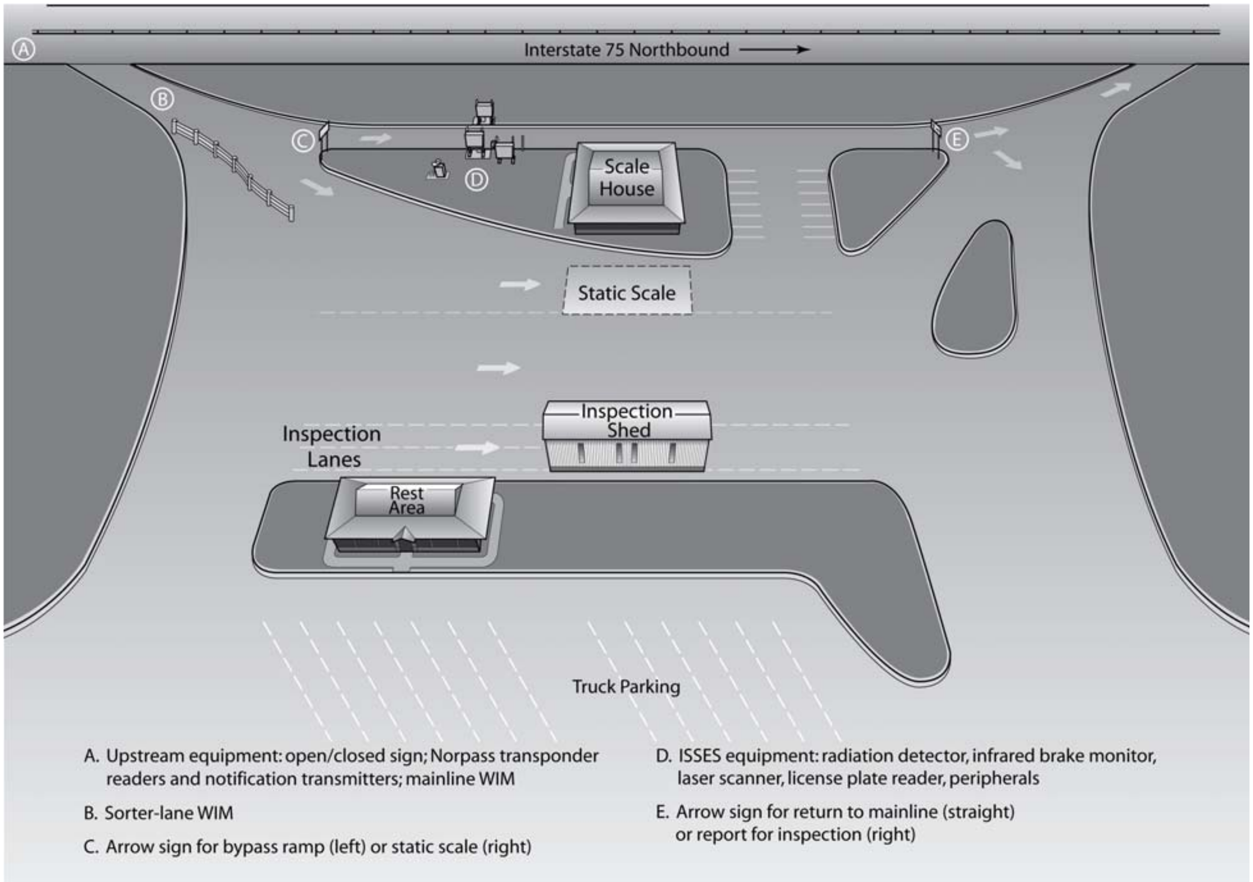


Figure 5. Layout of weigh-inspection station and traffic patterns at London, Kentucky (Laurel County) on northbound I-75. Illustration is not to scale.

Figure 6. Inspector using the inspection shed at Laurel County station to measure brake stroke during a routine safety inspection.

Summary of Evaluation Goals and Objectives

The independent evaluation conducted on behalf of the USDOT was intended to document the performance and benefits of the ISSES from a national point of view and provide practical information on commercial vehicle safety and efficiency that will be useful to other states considering the deployment of similar equipment. Safety-related results from the independent evaluation are also being incorporated into the national evaluation of the Commercial Vehicle Information Systems and Networks (CVISN) Deployment Program under a separate task order with the USDOT (2006d,e; 2007a). Two goal areas, with related objectives, guided the Kentucky evaluation:

Goal 1	***To estimate whether the ISSES will make highways measurably safer and more secure.***

Objective 1.1 Measure subsystem and integrated system performance characteristics.

Objective 1.2 Use data from the field test to determine the distributions of kinds of vehicles traversing the weigh station under normal conditions. This provides a baseline for reference in assessing the highway safety benefits of the ISSES.

Goal 2	***To determine how the ISSES makes the inspection process more efficient and effective, in turn contributing to improved highway safety.***

Objective 2.1 Determine the degree of user acceptance and the perceived usefulness and usability of the ISSES as deployed, and quantify deployment and operating costs related to the ISSES.

Objective 2.2 Measure the ability of the ISSES to improve inspection selection efficiency, and in turn to yield reductions in crashes and breaches of highway security.

Objective 2.3 Explore options for integrating the data available from the ISSES with existing safety, enforcement, and administrative data sources, and prepare models or plausible scenarios for Kentucky or other states to apply.

System Performance Evaluation

The purpose of the system performance evaluation was to assess how well the ISSES performed in the field, relative to its design and its intended use as described by the system vendor through information such as product literature, specifications, and training materials. The evaluation team attempted to determine the performance of the radiation monitor, the thermal inspection system, and the laser scanner.

As detailed below, the system in Laurel County appears to perform reasonably well in comparison with expectations, and considering that it is the first installation of its kind in the nation. The system displayed real-time visual and digital-format information about the trucks passing through the ISSES portal, permitted users to scan retrospectively through data screens showing visual imagery and digital data on previous passing vehicles, and produced usable data archives from the various subsystems, with some limitations. The user interfaces in the scale house were intuitive and seemed to be easy to learn, given appropriate training.

This assessment was affected by several important factors:

- The local ISSES was not yet integrated with any state or national databases of historical safety, inspection, out of service (OOS), or registration/licensing information, so it was operating in a stand-alone mode.

- The staffing levels at Laurel County were such that no KVE inspectors were assigned to use the ISSES as part of their mainstream job duties. The system was in place and operating during the evaluation period, but as noted in the user acceptance section below, in general no one was attending to the information shown on the ISSES display screens. The inspectors appeared to consider the system to be still something of an experimental or test prototype rather than an integral tool to achieving their day-to-day safety and law enforcement goals.

- Related to the previous factor, the deployment took place in a larger enforcement context that has up to now measured safety improvements (and provided incentives to inspectors) based on the numbers of inspections completed, not based on achieving high rates of OOS orders among a set number of inspections completed.

- At the request of FMCSA, the evaluation team was asked to disregard the performance of the ALPR and USDOT number reader systems. These two subsystems, which if effective could help KVE achieve important safety screening goals, did appear to be operating during the evaluation period.

- Some of the data that were planned to be collected (e.g., electronic screening bypass data for the first week of the field observation and thermal imaging video data from the Laurel County site) were not available.

System Components, Configurations, and Outputs

ISSES consists of the following component technologies:

- ▪ A vehicle detection and classification system, which uses a laser rangefinder to detect commercial motor vehicles (CMVs) and measure their speed, height, width, and length, facilitating the identification of vehicle types based on key characteristics (e.g., number of axles).

- An overhead camera that documents the passing of each CMV by capturing an image of the vehicle (Figure 7).

- A radiation detection system, which measures gamma and neutron radiation levels, to help inspectors recognize potentially hazardous material shipments and cargo. Inspectors at the station were also provided with a hand-held radiation detection and identification device, which can be used once a truck has been parked for closer inspection.

- A thermal imaging inspection system, which displays and records IR and visible video of the CMVs as they pass through the sensors, allowing inspectors to detect thermal/visual anomalies.

- An automatic license plate recognition (ALPR) system, which captures and stores wide-angle and narrow-angle digital images of the front of passing CMVs and performs OCR on the tractor front license plate numbers.

- A digital USDOT number recognition system, which captures digital images of the sides of passing CMV tractors and performs OCR on the USDOT number posted on the side of each tractor.

For further detail on the purposes and functions of the ISSES subsystems, see the Technical Report (USDOT 2008).

Several of the ISSES subsystems have dedicated computer servers located in the scale house at the weigh station. ISSES is designed for installation at CMV weigh stations, where it can be used by weigh station operators to identify potential problems and/or safety concerns with passing CMVs and to compile CMV traffic data and other statistics.

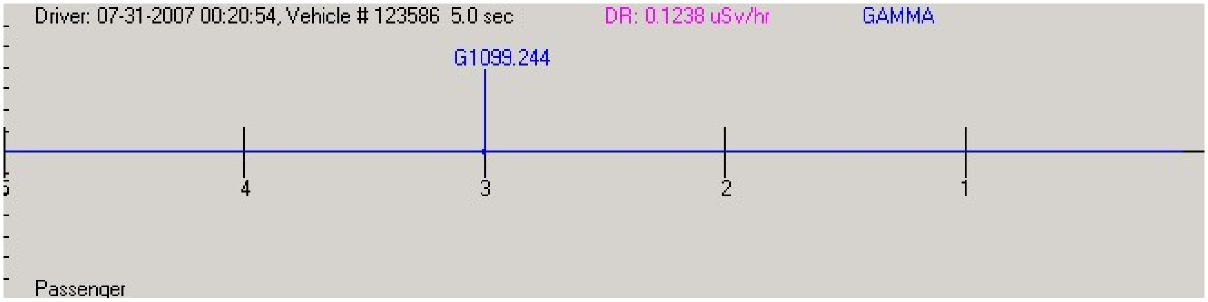
Figure 8 shows some of the ISSES components. The laser scanner apparatus is at right center, aimed downward at a slight angle toward the roadway. Four auxiliary photocell (conventional light beam) emitters/receivers are mounted in an "X" pattern on the upstream (left in photo) support poles of the two square, raised radiation portal monitors on either side of the roadway. These detection devices appear as small gray boxes in Figure 8. These electronic beams supplement the laser triggering system that detects the beginning and end of each passing vehicle.

Sample output files from the radiation monitor systems at the Kenton and Laurel sites are shown in Figure 9. While the underlying data are the same, the two JPG images are configured differently. The Kenton images depict a timeline, whereas the Laurel image superimposes a plan view of a generic commercial vehicle. If the monitor detects and alarm condition that exceeds a preset threshold, both formats provide the inspector or analyst with a visual cue as to the location of the emitting source relative to the geometry of the vehicle. The radiation monitor detects both

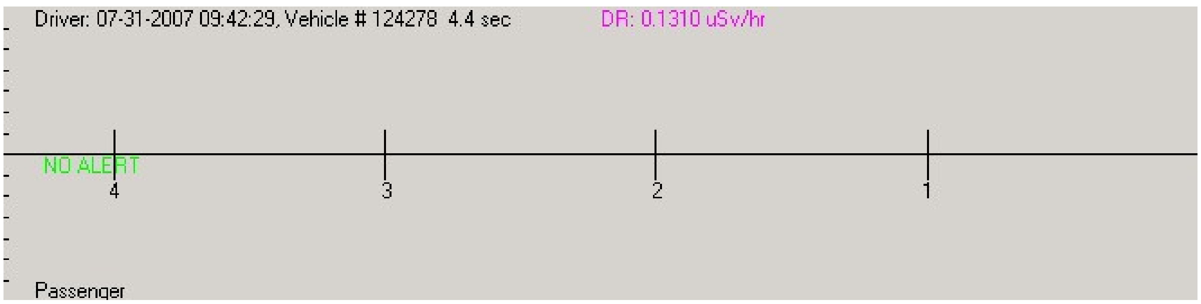
Figure 7. Example image recorded by overhead camera at the Laurel site.

Figure 8. Laser scanner for triggering and classification (far right) and raised radiation portal monitors (left and center-right).

a. Kenton – Gamma Alarm



b. Kenton – No Alarm



c. Laurel – Gamma and Neutron Alarms

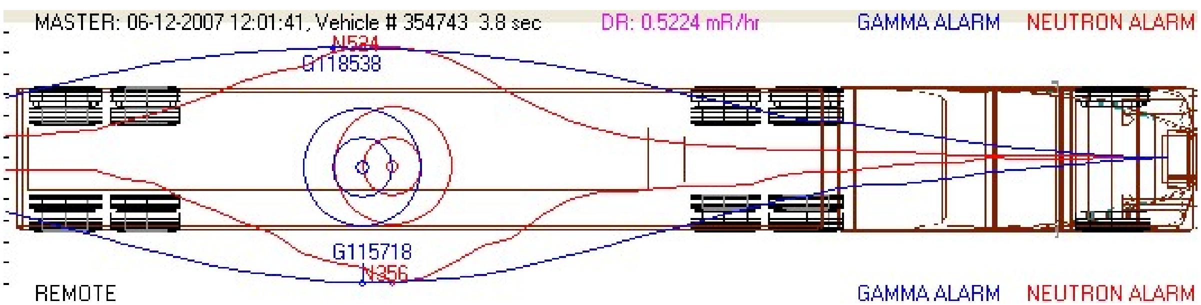


Figure 9. Graphic representations of radiation monitor output for CMVs passing through the Kenton and Laurel sites.

gamma- and neutron-emitting radiation sources, and sounds distinct alarms for each type of source if detected above the threshold.

Figure 10 shows the thermal image cameras mounted upstream of the scale house on a pan-tilt-zoom pedestal controlled by the operator in the scale house. One camera captures IR, and the other captures mixed IR/color images. A third video, separate from but integrated with the thermal imaging system, is captured by a gable-mounted color overview camera that has pan-tilt-zoom capability, but is normally focused on the ISSES truck portal. Figure 11 provides an example of a still image from the composite video captured at the Kenton site. The three main images show color video from the gable-mounted overview camera (top left); IR (top right); and overlay, or combined color/IR (lower left).

Figure 10. Location of thermal imaging video cameras at Laurel site, showing pan-tilt-zoom camera head.

Figure 11. Images captured by thermal imaging video cameras at Kenton site, as replayed on DVR viewer.

Figure 12 shows the two ALPR cameras, installed with slightly different orientations. One camera is pointed more toward the right side of the vehicle front, and the other camera is pointed more toward the left front. Figure 13 shows the configuration of the USDOT number reader camera, located at about the height of the center of the tractor (cab) door. Examples of images generated by the ALPR system are provided in Figure 14.

When a truck's USDOT number can be captured and interpreted by the ISSES optical character recognition system, ISSES generates a JPEG image of the portion of the vehicle containing the USDOT number with a date/time stamp corresponding imbedded in the event file name. An example JPEG image generated by the USDOT number reader is shown in Figure 15.

System performance data from ISSES deployments at weigh stations in Laurel County (northbound) and Kenton County (southbound) were included in this evaluation. The data used to assess system performance were collected during the following time periods:

- Laurel County station – 12:00 AM on June 11, 2007 through 11:59 PM on June 22, 2007 (12 days); and
- Kenton County station – 12:00 AM on July 31, 2007 through 11:59 PM on August 1, 2007 (2 days).

The research team visited the Laurel County site several times during the course of the field study. A data collector gathered USDOT numbers from all trucks passing through the ISSES portal for a two-week period during normal daytime hours (Figure 16). During these visits, members of the research team also conferred with KVE CMV inspectors, CMV police officers, and with vendor representatives from TransTech/IIS. Team members also observed the inspection selection process from inside the weigh station scale house, and they observed and photographed several inspections taking place (see Figure 6 above).

Research team members who visited the two deployment sites noted several structural or design differences between them, as outlined in Table 1. These differences illustrate some of the lessons learned in the first (Laurel County) deployment. The location of the visible lighting fixtures was changed at Kenton to reduce the amount of stray light reaching the mainline of traffic. Also, the lights at Kenton are positioned such that the light source is not visible to the approaching driver. The Kenton ISSES equipment was positioned approximately twice as far upstream from the scale house as the ISSES equipment at Laurel, in principle allowing Kenton inspectors more time to make decisions based on the system's output. One other change at Kenton was the placement of all of the ISSES above-ground portal apparatus, except one of the radiation panels, on the driver's (highway) side of the low-speed bypass lane. This change reduces the amount of equipment interfering with the sight lines between the passing vehicle and the inspector in the scale house, which is on the passenger side of the bypass lane.

Figure 12. Two cameras used for ALPR subsystem.

Figure 13. Rear view of USDOT number reader camera (at center foreground, on narrow post below two light fixtures). Two ALPR cameras are on larger post at right of USDOT camera.

a. Wide-angle – digits not recognized (no-read)

b. Wide-angle – digits identified

c. Narrow-angle/focused – digits not recognized (no-read)

d. Narrow-angle/focused – digits identified

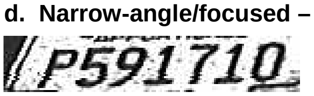


Figure 14. Images generated by the ALPR system.

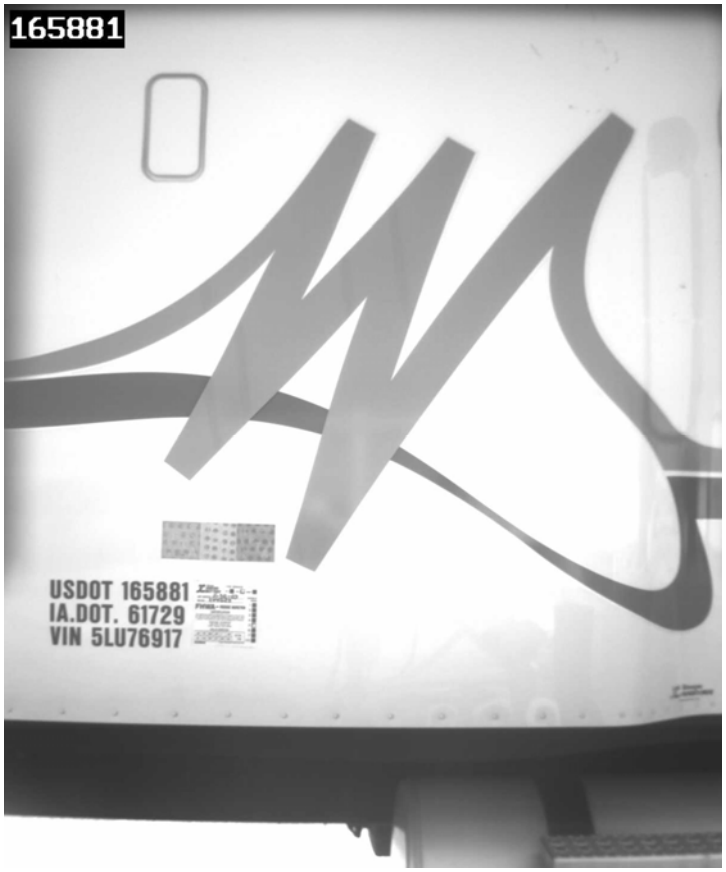


Figure 15. Image generated by USDOT number reader. Actual USDOT number is on passenger side of tractor cab (lower left). ISSES-generated OCR text conversion is superimposed at upper left.

Figure 16. Viewpoint of evaluation team data collector observing nearby commercial vehicle traffic after passing through the ISSES portal at Laurel County.

Table 1. Comparison of Laurel and Kenton station configurations.

ISSES Feature	Laurel	Kenton
Lighting fixtures for USDOT number reader	On passenger side, facing toward mainline	On driver side, facing away from mainline
Electrical supply conduits for lighting fixtures	Visible	Hidden
Mainline weigh-in-motion (WIM) scale	Yes	No
Sorter-Lane WIM scale	Yes	Yes
ISSES location relative to scale house	Closer to scale house	Further upstream from scale house
Radiation monitor panels	On raised pedestals	Lower, at grade level

The ISSES main system monitor allows the user to view a summary of the seven to ten most recent trucks to pass through the ISSES portal. Figure 17 shows an example of the ISSES continuous monitoring interface. Once the user has chosen a particular vehicle for further analysis, he or she can select any of a series of individual system views, including the radiation (rad) server, the DVR (digital video recorder) server for the thermal imaging system, the ALPR (plate) server, or the USDOT number server. The user chooses these subsystem server views from the management interface screen (Figure 18).

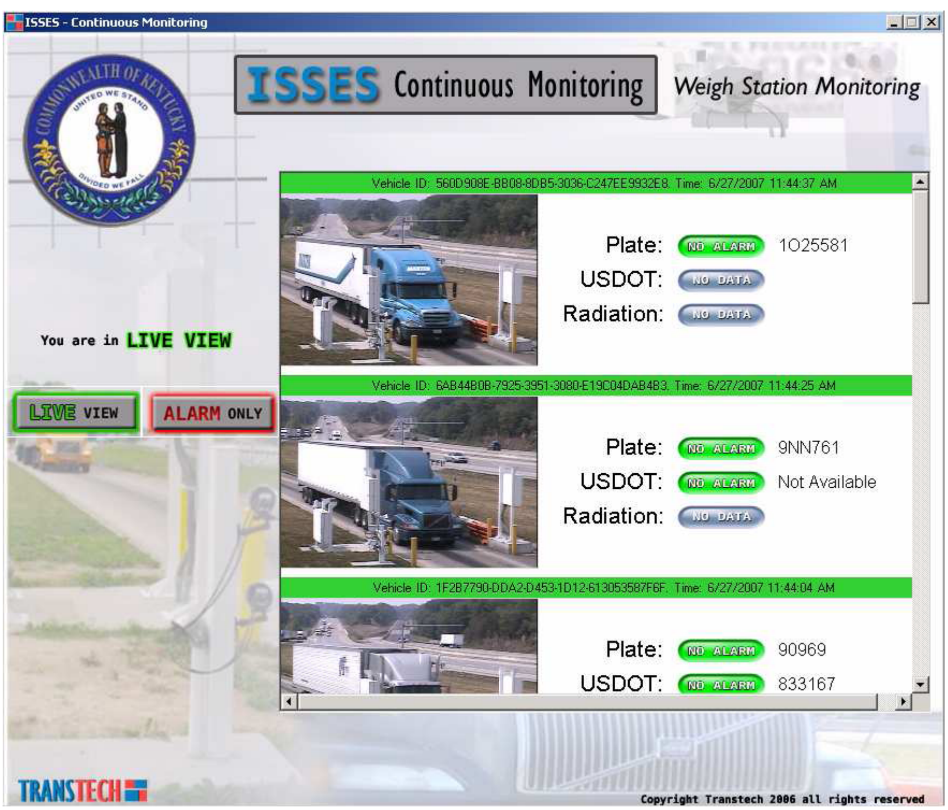


Figure 17. ISSES continuous monitoring interface, showing the "live view."

Figure 18. ISSES management interface, showing the server detail options at left.

System Performance Results

Laser Scanner (Vehicle Detection). There was some discrepancy between the number of vehicles counted by the research team staff member during site visits and the number of individual records generated by the software over the same time period. The software generated a significant number of records (i.e., distinct rows in the data file output produced by the software, which associates output for each vehicle from the radiation detector, USDOT number reader, overhead camera, and ALPR system in a single line) with "n/a" or "Not Available" values in columns that would normally contain OCR readings, file names, etc., which were not reported by the human observer.

At the Laurel site, for example, 1,769 records were generated by ISSES during a span of approximately 8 hours on June 14. During the same time period, the research team member recorded 1,455 vehicles, a difference of 314 records. ISSES components occasionally triggered when no vehicle was passing through the portal. This type of error is depicted in Figure 19, which shows three images recorded in close sequence by the overhead camera.

[1, first]

[2, middle]

[3, last]

Figure 19. Series of images recorded by ISSES overhead camera at Laurel site on June 14, 2007.

Each of these images is associated with a separate record in the ISSES output file. However, image [2] was taken after the vehicle shown in image [1] had already passed through the portal, but before the vehicle in image [3] reached the sensors. In other words, image [2] should not have been recorded and represents an extraneous record, or row, in the output file. In general, records that contained nothing but “n/a” or “Not Available” values were considered by the research team to be associated with one of these three types of errors.

The vendor acknowledged to the evaluation team that vehicle triggering and ordering the time sequence of actual events in the resulting data files has been a challenge in deployment. According to the vendor, the decision was made to allow a certain number of extra or false triggers, in exchange for having a system that is more likely to collect usable data on any vehicle suspected of posing a radiological threat.

Radiation Portal Monitor. The research team assessed the general output of the radiation portal monitor. During the 2-week field observation, the ISSES recorded nine neutron alarm vehicles and 558 gamma alarm vehicles. Considering the approximate number of vehicles recorded during this period (28,000), the neutron alarm was activated by one out of every 3,111 vehicles, and a gamma alarm was activated by one out of every 50 vehicles. The inspectors indicated that staffing levels prevented them from inspecting every truck that tripped a radiation alarm. A tendency for nuisance alarms caused by naturally occurring substances has the effect of making inspectors more likely to ignore all of the bulk gamma radiation monitor alarms, as confirmed in the user acceptance interviews. According to KTC, the Laurel County site was adjusted in the fall of 2007, after the time of the field observation, to greatly reduce the frequency of nuisance alarms.

As noted in Table 1 above, the radiation portal monitor panels at Kenton (and Simpson) were configured closer to the ground, in comparison to the Laurel County site, where the panels are raised several feet above the roadway. Figures 3 and 4 above illustrate the lower height of the Kenton and Simpson County installations. For comparison, the higher-profile panels at Laurel County are shown in Figures 1 and 2.

Inspectors at the Laurel site report that the alarm as currently configured is too sensitive to low levels of radiation. As a result, the alarm activates whenever a CMV carrying harmless but gamma ray-emitting materials (e.g., bricks, porcelain, clay, granite, cat litter, ceramic tile) passes through the station, and staff are prone to ignore the numerous gamma alarms. The gamma detector gives more nuisance alarms than the neutron detector.

The system vendor reported that the ISSES radiation detector subsystem will not be optimized until true “risk matrices” are cross-referenced with USDOT hazardous materials rules and remote data to automate useable transportation safety alarms for inspectors. This “rules manager,” which is the final stage in the development of ISSES, will cross-reference sensor data from ISSES with remote data stores to give user-defined alerts to operators. For example, the system is being programmed by the vendor to provide an audible alarm when some kinds of radiation-emitting loads are observed being hauled by a carrier whose USDOT number is not associated with the appropriate certificates, credentials, or permits.

The vendor indicated that live testing of the ISSES radiation monitor was conducted through the Domestic Nuclear Detection Office of the US Department of Homeland Security (DHS), and that the systems were confirmed to detect passing loads that were emitting radiation. The vendor reports having seen no evidence through testing that the radiation monitor has issued any false alarms (i.e., an alarm sounds when no radiation source is present). As opposed to false alarms, the tendency for nuisance alarms in the scale house when naturally occurring substances pass through the portal is discussed elsewhere.

Infrared/Thermal Imaging System. The research team reviewed two days' worth of video feeds captured by the thermal inspection device at the Kenton site. The objective was to determine whether potential heat-related defects were visible on the video and to track these defects. The independent review of the Kenton IR video was hampered by several factors. As indicated by the vendor, the IR camera from this period was used in a training exercise, mainly by untrained inspectors learning and using the system for the first time. The camera was not set up properly for the first seven to eight hours of the Kenton field study. Video images were extremely blurry (see Figure 20). At one point in the video, the camera settings were noticeably adjusted to provide the appropriate level of contrast between dark and light values (Figure 21).

This greatly enhanced the image; however, at the same time that the contrast was adjusted, the operator of the IR camera appeared to zoom in and pan the camera manually to move along with (i.e., track) each passing vehicle. This resulted in only a portion of the vehicle appearing in the IR camera viewer at any given time (see Figure 21). As a result, it was difficult to determine with any certainty that a particular tire, brake, or other component was giving off an unusual heat signature. These difficulties with the video image data appeared to be caused more by operator choices than by any inherent shortcoming with the technology.

The research team also noted a difficulty in correlating the image in the color (gable-mounted overview) camera viewer and the image in the IR camera viewer, on the three-part composite DVR player screen. As a vehicle approached the ISSES portal, it appeared on the IR viewer several seconds earlier than it appeared on the color monitor. This delay—most likely caused by the operator changing the aim of the IR camera while the overview camera remained stationary, or vice versa—was confusing, since the vehicle shown on the top right (IR) screen was often not the same vehicle visible simultaneously on the top left (color overview) screen (see Figure 21).

The research team was unable to cross-check video footage against Driver/Vehicle Examination Reports prepared by inspectors at the Kenton weigh station on July 31 and August 1, 2007, due to an inability to accurately identify the inspected vehicles on the IR/color video. USDOT numbers and/or license plate numbers from the inspection reports were used to find the date/time stamp on the USDOT number reader or ALPR output files and identify the time at which the vehicle passed through the ISSES portal. However, a review of the video at the corresponding times failed to identify vehicles with the same physical characteristics as those described in the inspection reports or shown in the still images captured by the ALPR/USDOT number reader.

Figure 20. Image taken while contrast on the Kenton IR camera was improperly adjusted.

Figure 21. Image taken from Kenton IR viewer after contrast adjustment (note the time lag between the IR and color images and the inability to view the entire vehicle in IR mode).

The research team watched video taken several minutes before and after the specified time, but could not conclusively match the images with the paper inspection records. When asked, the vendor indicated that the computer server that synchronizes the system time clocks at the Kenton site was down at the time of the recording, and the DVR clock did not match the ISSES clock. Because of this hardware fault, therefore, a direct, retrospective comparison was not possible, given the state of integration between the thermal imaging subsystem and the other ISSES vehicle identification and triggering subsystems when this sample of image data was stored. Such integration between the truck images shown on the overview color camera and the thermal/IR camera will be critical for enforcement and accurate vehicle identification in future enhancements of the ISSES hardware and software.

USDOT Number Reader and ALPR System. These systems were not under evaluation, so no results are presented.

System Performance Conclusions

The radiation monitor appears to alert inspectors to potential radiation hazards. No attempt was made to simulate radiation-emitting loads to formally test the rates of false positive alarms or false negative (missed detection) alarms. The alarm system produces different kinds of audible signals in the scale house, shows graphic images of the location and strength of the radiation source, and records quantitative information on the alarm conditions for retrospective review. A tendency for nuisance alarms caused by naturally occurring substances, however, has the effect of making inspectors more likely to ignore all of the gamma radiation monitor alarms, which reduces their effectiveness as a tool for identifying true threats. As a rule, the KVE inspectors do attend to neutron alarms, which sound different in the scale house and are much fewer in number than the gamma alarms.

The thermal inspection device enables inspectors to see potential heat-related defective or malfunctioning equipment that might be missed in a visual review. The field of view for the IR image can be manipulated as to direction and width, enabling close-up or wide-angle views of the stream of traffic. The system also records video data (in both IR and color/visible light) for later review. The effectiveness of the thermal inspection system appears to vary depending on the training, experience, and skills of the operator, especially in synchronizing the views of the ground-level IR/color camera and the gable-mounted color overview camera.

The laser scanner appears to log every truck passing through the ISSES apparatus, but its adjustment is such that the system generates a certain number of extra (blank) records or extra trigger events, which is an impediment to later review of traffic data. For the sample of data reviewed for this evaluation, some gaps in the time synchronization were noted.

The ISSES appears to perform with a minimum of unscheduled downtime. Partly owing to the exposed geographic location of the Laurel County weigh station, the hardware has been subject to several outages caused by lightning strikes and other power drops or interruptions. The system has experienced a low rate of hardware failure, other than some events related to the reliability of electrical power to the site. The developmental version of the system software is not equipped with a self-restarting function, which is expected to be included in production versions. Also, the state and the vendor are investigating the installation of an uninterruptible power supply system for the ISSES.

As of mid-2007, the system appeared to be at a late stage in the product development cycle, not completely in full-scale production mode, but well beyond the field test prototype stage. It was not yet integrated with any current or historical state or national databases, which affected its usefulness for real-time enforcement applications, but it appeared to be functioning well in stand-alone mode.

Inspection Efficiency Evaluation

Data to address the safety (inspection efficiency) goals and objectives described above were collected through various methods: (1) interviews and site visits with various KTC and KVE personnel; (2) a 2-week field study at the Laurel County inspection site in June 2007; (3) various federal and state safety data sources; and (4) past federal studies that relate to CMV crashes and safety. Listed below are the main data sources used.

- Interviews with KVE inspectors and KTC specialists
- USDOT numbers for all trucks going through the ISSES portal at the Laurel County station during a 2-week field study (during normal daytime hours).
- NORPASS (electronic screening/preclearance) bypass decisions per truck for one week during field study
- Electronic copies of inspections performed during 2-week field study
- Electronic copies of Kentucky statewide inspections spanning over 2.5 years
- SAFER (Safety and Fitness Electronic Record) carrier and inspection tables obtained from the Volpe Center at the time of the field study
- Kentucky Clearinghouse
- Large Truck Crash Causation Study (LTCCS)
- 2003 National Truck Fleet Safety Survey
- Large Truck Crash Facts – 2005.

The goal of roadside enforcement is to avoid as many crashes as possible by putting unsafe vehicles OOS before the OOS conditions present on the vehicle contribute to a crash. A means to this end is to improve the inspection selection process in such a way that the greatest benefit can result from a fixed number of inspections. This makes the most efficient use of limited time, human resources, and facilities. The overall approach of this evaluation was to first assess the effectiveness of the current inspection selection methods at selecting high-risk trucks.

In addition, alternative methods for selecting vehicles for inspection were evaluated based on potential availability of information from the above data sources. Several forms of available evidence and inspection selection methods were combined in various ways to develop hypothetical scenarios for the safety analysis:

- Selecting vehicles randomly for inspection, to provide a starting point from which to assess the contribution of the inspectors' knowledge and experience.

- The current vehicle selection process used in Kentucky, which relies primarily on inspector judgment.
- Using electronic screening[2] to eliminate all low- and medium-risk carriers from selection consideration, so that inspectors can focus on high-risk trucks or those with insufficient safety information in federal databases. This approach uses the carrier's ISS score, a rating system promoted by USDOT.
- Using the carrier's vehicle and driver OOS rates, which are the metrics preferred by Kentucky in roadside enforcement.
- Using information on OOS violations with a high relative crash risk
- Using thermal/IR brake images from the ISSES.

Finally, the evaluation measured the success of these new inspection selection methods by simulating what would happen if inspectors used these kinds of information to select high-risk trucks for inspection. The measures used to estimate success were the estimated number of crashes, injuries, and fatalities avoided.

Kentucky's current approach to inspection selection, which at some sites involves the use of the Kentucky Clearinghouse and historic out-of-service (OOS) rates, is described in the Technical Report (USDOT 2008). Also included in that report is a detailed account of the field observational study data collection, characteristics of truck traffic at the Laurel County station, a discussion of inspection efficiency (defined as the degree to which inspectors choose high-risk trucks for inspection), a discussion of current and potential future alternative approaches to increasing safety by improving the efficiency of selecting commercial vehicles for inspection, and an analysis of the usefulness of a carrier's credentialing status relative to their safety information in identifying high-risk trucks. This Summary Report focuses on only the results and implications of the inspection efficiency evaluation for commercial vehicle safety.

Table 2 presents a summary of large trucks involved in crashes in 2005[3] both nationally and within Kentucky.

Table 2. 2005 crash statistics for Kentucky and nation

	Kentucky	Nation
Large Trucks involved in Crashes	2,853	441,000
Fatalities	124	5,212
Injuries	1,858	114,000

Source: FMCSA 2005 Large Truck Crash Facts (Nation) (USDOT 2007b).
Fatality Analysis Reporting System (FARS), Motor Carrier Management Information System (MCMIS).

The most important benefit expected from the deployment of the ISSES and other CVISN technologies, especially electronic screening and safety information exchange, is a reduction in

[2] The term "electronic screening" is defined, for purposes of this study, as using any computer-based, real-time information source to aid in selecting trucks for inspection, whether the truck carries a transponder or not, and whether the screening occurs at mainline or ramp/sorter-lane speeds. Further details are provided below.
[3] Although more current crash statistics are available, the safety benefits analysis is performed using a baseline year of 2005 because that was the last year for which complete data were available from all of the relevant sources.

CMV-related crashes through improved enforcement of the Federal Motor Carrier Safety Regulations (FMCSRs). The principal hypothesis to be tested is that the ISSES and CVISN technologies will help enforcement staff focus inspection resources on high-risk carriers. This will result in more OOS orders for the same number of inspections—thereby removing from service additional trucks and drivers that would have caused crashes because of vehicle defects and driver violations of safety regulations.

Table 3 lists some key safety statistics obtained from the published literature. Most of these data are used in the crash avoidance analysis; others are provided for reference. According to FMCSA, 8.5 million large trucks in 2005 traveled approximately 233 billion miles in the U.S. Also in 2005, the last year for which complete statistics are available, 441,000 trucks were involved in crashes, resulting in approximately 114,000 injuries and 5,212 deaths. In order to determine the impact of removing OOS violators from the roadway on the number of crashes, it is necessary to estimate certain probabilities associated with crash causation. One important component to the statistical crash reduction model is being able to estimate the relative risk of driver and vehicle OOS violations in truck crashes. Specifically, we would like to know the probability that an OOS condition exists on a truck given a crash has occurred involving that truck. Before the FMCSA-sponsored LTCCS, there were not reliable estimates of this probability for either vehicle or driver OOS violations as there had not been sufficient data to support calculation of reliable estimates. By focusing on the pre-crash condition of the truck, the LTCCS provides the right type of data for this analysis. The LTCCS data was used to calculate various probabilities that were used as inputs to the crash avoidance model (USDOT 2006a).

Summary of Safety Modeling Approach

Ultimately, safety benefits will be realized only to the extent that targeted inspections and improved compliance translate into reductions in numbers of crashes. The premise of targeted inspections is that, for the same number of inspections performed, additional drivers and vehicles operating with OOS conditions will be removed from the roadway. Furthermore, all of the conditions leading to the OOS order will be fixed and "stay fixed" for a period of time after the inspection. Therefore, crashes that would have occurred during this period are prevented because the OOS conditions that would have caused the crashes were eliminated. The safety benefit of ISSES and CVISN technologies is determined by comparing the number of crashes avoided under a baseline scenario (i.e., with pre-ISSES or CVISN roadside enforcement strategies and technology) with the number of crashes avoided under a number of deployment scenarios involving the ISSES and CVISN. It is assumed under each scenario that the corresponding number of injuries and fatalities avoided are proportional to the number of crashes avoided.

A statistical model of crash avoidance was developed, based on research on the Safe-Miles model developed for FMCSA at the Volpe Center to estimate the benefits of MCSAP, the Motor Carrier Safety Assistance Program (VNTSC 1999). Although the model used in the present Kentucky safety benefits analysis is different from the one used in Safe-Miles, certain model parameters such as the number of "safe miles" a truck travels following an OOS order, were used in this Kentucky analysis. The approach to safety benefits estimation in the Kentucky evaluation was adapted from the approach documented in Chapter 5 of the CVISN Model Deployment Initiative (MDI) Evaluation (USDOT 2002).

Table 3. Relevant national safety and safety enforcement statistics on large trucks.

Statistic Description	Value	Source [1]
Number of large trucks	8.5 million	Large Truck Crash Facts 2005 (USDOT 2007b)
Large truck annual vehicle miles traveled (VMT)	233 billion	Large Truck Crash Facts 2005 (USDOT 2007b)
Large trucks involved in crashes (2005) Injuries from large truck crashes (2005) Fatalities from large truck crashes (2005)	441,000 114,000 5,212	Large Truck Crash Facts 2005 (USDOT 2007b)
Large trucks involved in property damage-only crashes Large trucks involved in injury-only crashes Large trucks involved in fatal crashes	354,000 82,000 4,932	Large Truck Crash Facts 2005 (USDOT 2007b)
Large truck crash rate (truck crashes/100 million VMT) = 441,000 truck crashes/233 billion VMT	189.3	Derived
Commercial vehicle (non-bus) vehicle inspections performed (2005) Commercial vehicle (non-bus) driver inspections (2005) Total CV (non-bus) inspections (driver or vehicle) (2005) Kentucky annual commercial vehicle (non-bus) vehicle inspections performed (2005) Kentucky annual commercial vehicle (non-bus) driver inspections performed (2005) Kentucky annual commercial vehicle (non-bus) (driver or vehicle) inspections performed (2005)	1,949,375 2,669,679 2,708,856 44,142 86,028 86,077	Annual Summary of Roadside Inspections – NAFTA Safety Stats (A&I website, USDOT 2005b) Kentucky Historical Inspection Data
Percent of vehicles placed OOS (2005) Percent of drivers placed OOS (2005) Kentucky percent of vehicles placed OOS (2005-Sept 2007) Kentucky percent of drivers placed OOS (2005 – Sept 2007) Kentucky percent of vehicles or drivers placed OOS (2005 – Sept 2007)	24.0% 7.0% 9.5% 4.7% 13.6%	Annual Summary of Roadside Inspections – NAFTA Safety Stats (A&I website) Kentucky Inspection Data (2005 – Sept 2007)
Percent of VMT with vehicle OOS conditions (2003) Percent of VMT with driver OOS conditions (2003) Percent of inspections that found at least one OOS vehicle violation given a OOS driver violation was found Percent of VMT with brake-related OOS conditions	28% 5% 49% 14%	2003 National Truck Fleet Safety Survey (TFSS) (USDOT 2006b) 1996 National Survey (Star 1997)
Percent of large CMV crashes with vehicle OOS condition present	32.4%	Derived from LTCCS
Percent of large CMV crashes with driver OOS condition present	17.2%	Derived from LTCCS

1 Full reference citations are presented at the end of this report.

To summarize, the statistical model used terms such as the following:

- The probability that a truck has an OOS violation given that it was inspected
- The probability of a crash given that a vehicle has an OOS violation
- The probability that a vehicle has a particular OOS violation or group of violations (e.g., vehicle or driver OOS condition) given that it is in a crash (based in part on LTCCS crash factors data)
- The probability of a crash
- The probability that a vehicle has an OOS condition
- The national crash rate for large trucks
- The number of safe miles (SM) traveled as a result of "fixing" an OOS condition.

National data on rates of injury and fatality per truck-involved crash were used to derive the numbers of injuries and fatalities that could be avoided, given a certain number of crashes avoided.

Deployment Scenarios

Truck traffic at most inspection sites is very heavy, and inspectors cannot inspect every CMV that passes by. Thus, there needs to be a sound methodology for narrowing down the pool of trucks from which inspectors have to choose. Seven overall scenarios are presented in this section, a few of which have been divided into sub-scenarios. The seven deployment scenarios present different methods for selecting vehicles for inspection with the goal being to select trucks that yield the most OOS orders. Using the crash avoidance model, these scenarios illustrate the estimated safety benefits of the ISSES and other CVISN technologies. Table 4 provides a high-level summary of the seven scenarios presented in this section. A more thorough description of each roadside enforcement (RE) scenario follows the table.

Table 4. High-level overview of roadside enforcement scenarios.

	Screening Criteria Used in Scenario						
Scenario Number	**Random Only**	**Inspector Experience and Judgment**	**Electronic Screening with Snapshots**	**KY OOS Rate Algorithm**	**Vehicle and Driver OOS Rates Using Threshold**	**Brake and Driver OOS Rates**	**Infrared Images and Driver OOS Rate**
RE-0	X						
RE-1		X					
RE-2		X	X				
RE-3		X	X	X			
RE-4		X	X		X		
RE-5		X	X			X	
RE-6		X	X				X

RE-0: Random Selection. Enforcement officers (inspectors) select CMVs for inspection in a random manner without using personal experience, judgment, or any ISSES or CVISN technologies. This is not one of the roadside enforcement strategies being considered, nor is it a realistic strategy to employ. However, the calculation of safety benefits under this scenario is useful for determining the contribution of the inspectors' knowledge and experience during the vehicle selection process.

RE-1: Baseline—Pre-ISSES/CVISN. Inspectors select CMVs for inspection using personal experience and judgment, but without the aid of ISSES or most CVISN technologies. Electronic screening is assumed to be used at its current level as of June 2007. This baseline scenario is analyzed twice. First, safety benefits are calculated based on Kentucky vehicle and driver OOS rates, which are significantly lower than the national average. Then, the analysis is performed assuming that Kentucky's vehicle and driver OOS rates were on par with national estimates—referred to as RE-1a.

RE-2: Mainline Electronic Screening based on ISS Score. State deploys electronic screening with safety snapshots at all major inspection sites. Motor carriers that are classified as low- and medium-risk based on ISS scores (comprising approximately 60 percent of trucks on the road) enroll in the electronic screening program, are equipped with transponders, and are allowed to bypass inspection sites. Inspectors use current practices to select vehicles for inspections from the remaining 40 percent of trucks in the high-risk and insufficient data categories.

RE-3: Electronic Screening based on Kentucky OOS Rate Inspection Selection Algorithm. State utilizes Kentucky OOS rate inspection selection algorithm at all inspection sites that utilize electronic screening. Every vehicle that enters the inspection station is identified accurately by the ISSES' ALPR and USDOT readers. Safety information for each carrier is obtained from the Kentucky Clearinghouse. Based on the safety information, the algorithm identifies trucks for inspection as described in Section 6.2. Inspectors select vehicles for inspection from this pool of identified trucks, while non-identified trucks continue to the mainline. Trucks with transponders are subject to the same algorithm already built into NORPASS.

RE-4: Electronic Screening based on high vehicle and/or driver OOS rates. State utilizes the ISSES and/or electronic screening at all major inspection sites. This scenario is similar to RE-3 in that each truck is screened via the ISSES based on the vehicle and driver OOS rate of the carrier. However, RE-4 differs in that a threshold OOS rate is established for both vehicles and drivers such that all trucks with OOS rates exceeding the corresponding thresholds are brought into the inspection station for inspection, while all others are allowed to bypass inspection sites. The threshold rates are chosen such that only trucks with the highest OOS rates are candidates for inspection. The threshold values can vary depending on both the truck traffic and the rate at which inspections can be performed at the site. As part of RE-4, three specific threshold values are considered.

RE-5: Electronic screening based on high driver OOS or brake violation rates. State utilizes the ISSES and/or electronic screening at all major inspection sites. Each truck is screened via the ISSES based on its OOS or violation rate for violations that have a high relative risk for crash. In this scenario, vehicles are screened based on their brake violation and overall driver

OOS rates as they appear in SAFER. A distinction is made here between violation and OOS rates. SAFER contains a *violation* rate for brakes but not a brake *OOS* rate. Thus, violation rates are used as a safety index for brake issues, while the driver OOS rate is used to screen for driver issues. Both brakes and driver OOS violations have been found to have a high relative risk for crashes. This scenario differs from RE-4 in that vehicles are screened on their brake violation rate as opposed to their overall vehicle violation rate in an attempt to catch those vehicles that have a violation that has a higher relative risk for crash. Similar to RE-4, all trucks with violation rates exceeding the threshold are candidates for inspection, while all others are allowed to bypass inspection sites. Moreover, the threshold rates are chosen such that only trucks with the highest rates are selected for inspection and the thresholds can vary depending on the amount of inspection personnel available at a given station. As part of RE-5, three specific threshold values are considered.

RE-6: Electronic screening based on infrared screening and high driver OOS violation rate. State utilizes the ISSES at all major inspection sites. Each truck is screened via two criteria: the thermal (IR) imaging system on the ISSES and the driver OOS rate of the carrier. In this scenario, vehicles are screened based on the presence of a brake violation through the IR image produced by the ISSES and the driver OOS rate as it appears in SAFER. This scenario is similar to RE-5 in that both brake and driver OOS violations are used as screening criteria. RE-6 differs from RE-5 in that vehicles are screened for brake violations via IR imaging as opposed to brake violation rates obtained from SAFER. All trucks with a potential brake violation as detected from the IR image or trucks with driver OOS rates exceeding various thresholds are candidates for inspection, while all others are allowed to bypass inspection sites. Inspection efficiency data from an earlier FMCSA report on the IRISystem (USDOT 2000) were used in this scenario.[4]

In summary, RE-0 is the most basic selection process of selecting vehicles randomly and is presented mainly to assess the contribution of the inspectors' knowledge and experience during the vehicle selection process, which is represented in the baseline scenario RE-1. The remaining five scenarios all make use of progressively more involved selection criteria. Electronic screening is employed in RE-2 to eliminate all low- and medium-risk carriers from selection consideration. Although this scenario helps improve inspection selection efficiency by allowing inspectors to focus only on high-risk vehicles or those with insufficient data, there are still too many vehicles remaining in these categories for roadside enforcement officials to inspect them all. As a result, scenarios RE-3 through RE-6 provide various methods to further narrow down the number of vehicles that inspectors have to choose from. RE-3 is based on the Kentucky OOS rate inspection selection algorithm, which selects vehicles for inspection at different rates depending on their OOS rates. RE-4 and RE-5 take a slightly different approach in selecting only those vehicles with the highest probability of having particular kinds of OOS violations as measured by some safety index. RE-6 examines the benefits when IR imaging is used to screen for brake violations.

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[4] The IRISystem technology was purchased by IIS (the vendor for the ISSES technology under evaluation) in 2003. IIS continues to manufacture IRISystem vans, and the IRISystem designer participates in all of IIS's thermal imaging applications.

Broader Definition of "Electronic Screening"

In the CMV law enforcement community, the term "electronic screening" signifies a transponder-based mainline preclearance system, such as NORPASS, HELP/PrePass, Oregon Green Light, or equivalent. Such systems provide roadside enforcement personnel the ability to detect and identify and (optionally) weigh CMVs at mainline speeds. For purposes of this report, Scenarios RE-3 through RE-6 expand the definition of "electronic screening" to include other means of achieving a similar goal, namely to use computers and telecommunication technology to identify and prescreen vehicles in real time. In Scenarios RE-3 through RE-6, ISSES or an equivalent system is used for identifying trucks moving slowly through a weigh station. The basic function is the same as transponder-based preclearance, the only difference being the truck's speed at the point of decision (red light, pull-in, green-light, bypass). In these four scenarios, it is assumed that some trucks carry transponder tags and some do not. Furthermore, it is assumed that all trucks approaching the station are subject to electronic or computer-based, real-time prescreening—at high or low speeds—as an aid to the inspector's decision process. These four scenarios also diverge from the usual definition of "electronic screening" in that, for purposes of modeling and analysis, they introduce screening decision criteria that are different from the criteria believed to be used in the prevailing mainline e-screening programs or partnerships (NORPASS, PrePass, and Oregon Green Light).

Summary of Safety Benefits/Inspection Efficiency Results

Table 5 summarizes the major results of this safety benefits analysis. According to the model, current roadside enforcement strategies (RE-1) are responsible for avoiding 126 truck-related crashes, which represents about 4.4 percent of the 2,853 crashes in Kentucky that occur annually, based on 2005 crash statistics. Furthermore, it is estimated that current roadside enforcement activities are responsible for preventing 33 injuries and 2 deaths.

The safety benefits realized increases with each scenario RE-2 through RE-6. The maximum benefit is achieved with RE-6, where 755 crashes are avoided if the top 5 percent of vehicles in terms of driver OOS violations are inspected in conjunction with IR screening. This implies that about 26 percent of Kentucky's 2,853 annual truck-related crashes could be avoided under RE-6. In reality, this figure is an overestimate, because national crash rates were used in the safety benefit calculations, because reliable crash rates for Kentucky were not available.

To put the crash avoidance numbers into context, consider that the number of large trucks involved in crashes in Kentucky (2,853) is low relative to the 441,000 large trucks involved in crashes nationally, representing only 0.6 percent of national crashes. Also, the percent of Kentucky crashes relative to the number of inspections performed in Kentucky is about 3.3 percent. Comparatively, the national rate of crashes relative to the number of inspections is about 16 percent. Therefore, relative to the number of inspections, Kentucky's crash rate is smaller than the national crash rate. The exact reason for this is unknown, but possible explanations include a lower volume of traffic in Kentucky, less congested highways, or a smaller number of large cities.

Table 5. Estimated safety benefits of the ISSES and CVISN under selected deployment scenarios and assumptions.

Scenario	Description		Numbers of Safety Events Avoided[1]			Additional[2] Safety Events Avoided (ISSES/CVISN Benefit)		
			Crashes	Injuries	Fatalities	Crashes	Injuries	Fatalities
RE-0	Random Selection		183	47	2			
RE-1	Baseline – Pre ISSES/CVISN Using Kentucky OOS Rates		126	33	2			
RE-1a	Pre ISSES/CVISN Using National OOS Rates		214	55	3			
RE-2	Mainline Electronic Screening Based on ISS Score		189	49	2	63	16	0
RE-3	Electronic Screening based on Kentucky OOS Rate Inspection Selection Algorithm		227	59	3	101	26	1
RE-4	Electronic Screening based on high vehicle and/or driver OOS rates[3]	5%	306	79	4	180	46	2
		10%	217	56	3	91	23	1
		25%	134	35	2	8	2	0
RE-5	Electronic screening based on high driver or brake violation rates[3]	5%	476	123	6	350	90	4
		10%	353	91	4	227	58	2
		25%	221	57	3	95	24	1
RE-6	Electronic screening based on infrared screening and high driver OOS violation rate[3]	5%	755	196	9	629	163	7
		10%	644	167	8	518	134	6
		25%	544	141	7	418	108	5

1 The estimated number of crashes avoided is based on the assumption that crashes are avoided when vehicles and drivers with safety violations are placed OOS.

2 Compared to baseline scenario (RE-1).

3 Safety Benefits shown for strategies RE-4, RE-5, and RE-6 are dependent on the percentage of the truck population selected for inspection (top 5%, 10%, or 25% in terms of risk).

Recalculating the safety benefits achieved when the national number of vehicle and driver inspections in 2005 is used instead of Kentucky inspection figures finds that implementing RE-6 avoids about 6.5 percent of all national crashes. This figure makes more sense in the context of the number of total crashes.

It is not possible to know the exact percentage of crashes caused by driver or brake OOS violations. However, as discussed earlier, there is a 12.2 percent increase in relative crash risk for driver OOS violations, a 4.4 percent increase in crash risk for vehicle violations, and a 7.7 percent increase in crash risk for brake OOS violations. Since a vehicle could have more than one type of violation, the three crash risk figures cannot be added to obtain the total increase in crash risk. However, these figures suggest that if there were no driver or brake OOS violations present in the population, no more than about 20 percent of crashes could be avoided. This is the maximum possible benefit if all OOS violations were removed from trucks traveling on the road. This fact helps to put the Kentucky results into context and to provide an upper bound on the crash avoidance numbers for Kentucky.

User Acceptance and System Cost Evaluation

The user acceptance study focused on the interface between the inspectors and the ISSES equipment, and the more subjective attitudes and contextual environment that affect the adoption or rejection of advanced systems such as the ISSES. For completeness, the user acceptance interview questions were intended to cover all ISSES subsystems, including the ALPR and the USDOT number reader, even though those two systems were not under evaluation. Details on the user acceptance and system cost data collection, including interview guides and transcripts of interview contents, are presented in the Technical Report (USDOT 2008).

User Acceptance Results

The purpose of this section is to summarize the findings of the interviews and site observations and to present a discussion of the prevailing themes that appeared in the user acceptance data. The main two findings are as follows:

1. **Staffing and training were seen as main barriers to active use of ISSES in everyday KVE inspection operations.**

2. **The majority of inspectors said ISSES appeared to be user-friendly, and that training is necessary to help them make full use of its capabilities.**

Several prevailing themes appeared in the data, as described below:

Training. In many replies, respondents cited lack of proper training as being either the main reason or part of the reason they had not used any part of the ISSES equipment. In many instances, respondents indicated that with adequate training and user documentation they could come to appreciate and utilize the equipment. According to KTC, some training and exercises had been conducted at the time of the initial deployment in 2005 and since then; however, training should be offered frequently for all staff, especially new hires. Staffing levels were also seen as an important barrier to using ISSES during daily inspections. There is a perceived scarcity of staff resources to make use of the information being generated by ISSES.

Based on respondent feedback, training should include a discussion of how ISSES can augment current inspection selection practices, which are primarily visual inspection and observation, the use of WIM sensors, and queries of external data sources. For the radiation monitor, training should highlight how to interpret the truck profiles listed on the ISSES screen and how to distinguish and read radiation dose rate values. For the thermal imaging equipment, training should include a thorough explanation of scenarios in order for inspectors to be able to recognize brake violations and other patterns. Three of the six respondents felt that the thermal imaging device should benefit them since it seemed “easier to locate possible brake defects” than working at a location without it.

Equipment. Respondents provided most useful information about two of the ISSES subsystems, the radiation monitor and thermal imaging device. In many replies, respondents considered most ISSES radiation alarms to be caused by routine, naturally occurring substances (e.g., brick, porcelain, clay) or licensed, placarded medical products. Respondents indicated the radiation monitor needs to be fine-tuned to reduce nuisance alarms. The system is perceived as “very sensitive.” Inspectors do not want to waste time chasing down every truck.[5] [As a point of reference, during the field observation, approximately 500 gamma alarms and nine neutron alarms were recorded by ISSES in 12 days.] According to the vendor, every ISSES site is provided with a hand-held radiation detector, along with software allowing inspectors to download data from the hand-held detector to the electronic record of the inspection. Several respondents noted that hand-held radiation detectors, while not recognized by them as being part of ISSES, complemented the radiation portal monitor. The hand-held device, which is deployed at every ISSES site, can zero in on a problem when the truck is in the inspection shelter.

In many answers, respondents indicated that they rely on the thermal imaging device with the greatest confidence because they can “actually see trucks on the screen” and believe it enables them to perform their job functions better. It appears to be easy to use, even given little training, and training could only help inspectors make better use of this subsystem. Respondents also said that having the thermal imaging device on site has more benefits than IRISystem vans, although one could complement the other, similar to the combination of the hand-held and fixed portal radiation monitors. On several occasions, respondents raised the point that the thermal camera shows only one side of truck, and they would like to be able to view both sides of the vehicle as it passes the thermal camera location. One characteristic of the thermal imaging system is that it tends to show defects more clearly on the far-side axles of the truck, partly because the tires and rims do not obstruct the line of sight from the camera to the brakes and other components that are most subject to over- or under-heating. Cameras placed on both sides of the lane of travel would thus allow the inspector to view the insides of the wheels on both sides of the truck more clearly.

Lessons Learned. Respondents provided useful lessons learned regarding how ISSES would yield greater benefits for future deployments if it were integrated with state and national systems:

[5] The KTC indicated that the nuclear detection subsystem at the Laurel County ISSES site had been adjusted in the fall of 2007 (after the time of these interviews) to greatly reduce the frequency of nuisance alarms.

Lesson learned 1: Train early and retrain periodically to account for new staff. Respondents speculated that they could provide additional input or different answers to the user acceptance interview questions if they had had training on the equipment, since many respondents admitted their unfamiliarity with the equipment. Future evaluations could include revised one-on-one interviews as well as focus groups to bring together several trained users in a group setting to discuss and listen to their issues and concerns about the features of the ISSES.

Lesson learned 2: Carefully consider where equipment is sited before installation and obtain input from inspectors. As it is installed now, it appears that the equipment is located too far down the approach ramp from the mainline, at a point that is too close to the scale house. Inspectors need adequate time to interpret information from ISSES and then decide whether to stop a given vehicle. In the current setup, by the time the vehicle arrives, it is often too late; inspectors need more time to visually inspect IR imagery and other ISSES signals. The Kenton site, installed after the Laurel site, provided more distance from the ISSES equipment to the scale house, primarily for the time required for the system to recognize and process the USDOT numbers and license plate numbers.

Changing the siting of the equipment could also help the triggering and correlation process, especially when two trucks are very close together in line. The current ISSES occasionally generates extra data records across the various subsystems, making it difficult to relate, for example, ALPR values with USDOT number values, or with radiation profile values. The topic of triggering issues, including the tradeoffs required when deploying a system that combines both highway safety and homeland security functions, is covered in more detail above in System Performance.

Lesson learned 3: Provide equipment documentation and user guides along with contact information on-site (e.g., if a radiation alarm goes off) that affords inspectors access to personnel with a working knowledge of equipment.[6]

Overall, the ISSES system works as designed, but KVE staff—because of their workload, primary duties, and enforcement performance measures—perceive watching the ISSES screens to be very time-consuming in terms of meeting the quotas that are set out for them in their jobs.

Deployment and Operating Costs Results

The system cost study focused on the economic dimensions of the deployment, for both one-time start-up costs and recurring (annual) costs to operate and maintain the ISSES. Data on actual costs incurred were supplemented by best estimates for those costs that are not available.

Data collection for the system deployment and operating costs was made via contact with the KTC to identify the various costs associated with purchased and installed materials and system equipment, related software integration, and vendor labor. The KTC has provided a copy of a bill of sale dated 6/2/2005 with cost data and general system specifications. This bill states that

[6] KTC indicated that, now that a maintenance contract has been established with the vendor, each ISSES site has contact information posted for the on-site technical support person from IIS, giving KVE enforcement personnel consistent access to help if they have a question or a problem with the equipment.

the total cost of installing ISSES at the Laurel County weigh station was $350,000. This total cost includes the: radiation detection component; thermal imaging component; license plate reader component; and site preparation and installation. All installed equipment is included in the bill of sale except two rack mount servers. The KTC, which was involved in ISSES contracting between the state and the vendor, reported that funds from Oak Ridge National Laboratory (ORNL) were also used in the original Laurel County installation and deployment, and that subsequent systems installed in other Kentucky counties have actually cost the state approximately $500,000 each to procure and install.

The original budget for the Laurel County ISSES did not provide funding for training or system maintenance. According to the KTC and the vendor, however, recurring (annual) costs for hardware to operate and maintain the equipment have been fairly low. The system is based on low-amperage sensors and communication systems, and does not cause a large electrical current draw. Equipment repairs and replacement of parts, as described below, have been largely due to lightning strikes and electrical power service interruptions, not due to ISSES equipment defects. In November 2006, the KTC entered into a service contract with TransTech to make one field technical support person available at approximately 60% of full-time on-site to cover the three installed ISSES locations for one year, and at about half of the first year's time commitment for two years thereafter. While the technical support person also participates in client- and vendor-driven data collection projects and other activities outside of this on-site service commitment, his main role is to be available to troubleshoot any maintenance issues, monitor the site remotely, make any repairs on-site as needed or requested by KVE or KTC, provide training to operators/inspectors at each of the sites, and identify and test ISSES enhancements.[7] The cost of this maintenance and technical support from November 2006 through August 2007 has been approximately $109,000. This amount has covered the ISSES maintenance duties listed above, but some fraction of the field support technician/analyst's time within this contract has been devoted to administrative activities, software programming support, and communications protocol development for the nuclear detection subsystem unrelated to the monitoring, repair, and maintenance of the ISSES. Thus, the entire $109,000 has not been attributable to operating and maintaining the ISSES hardware and software.

It appears that ISSES requires frequent maintenance because of system troubleshooting and power interruptions, the latter type being considered unscheduled maintenance. It is difficult to delineate whether the maintenance (both unscheduled and preventive/planned) is monthly, weekly, or daily because of the nature of the troubleshooting (e.g., lightning strike versus software modification).

[7] The first such training session was a two-day training session held on July 31 and August 1, 2007, provided to personnel at the Kenton County inspection station. The training session focused on the operation of the thermal imaging system.

Conclusions and Implications

The conclusions and lessons learned, presented below, are based on the findings in the Technical Report on the Kentucky CVSA Evaluation (USDOT 2008). Users can refer to the Technical Report for further detail on any conclusions here whose supporting documentation is not given in this Summary Report.

Overall Conclusions and Lessons Learned

- The KVE inspectors at Laurel County were not using the ISSES to any great extent during the period of the field study. According to interviews with inspectors and with staff from the KTC, the ISSES hardware was functioning satisfactorily, but the state's scarcity of resources and staff prevent inspectors from having the time to use the information being displayed by the ISSES. The ISSES was in place and operating at the inspection station, but was not being used to any effective extent during the period of the evaluation.

- The portions of the ISSES under evaluation in this study appeared to perform as designed. KVE staff assigned to the Laurel County weigh station, because of their workload and their primary inspection duties, tend to perceive that spending time watching the two ISSES interface screens or monitors is too time-consuming and does not represent an efficient use of their time. The ISSES software and components now deployed—though operational—are considered to be in a development mode as of late 2007.

- The vendor informed the evaluation team that the company attempted to use commercial, off-the-shelf technologies for the ISSES whenever possible. While this approach provides advantages with respect to reducing first costs and allowing the state to begin using subsystems like the thermal inspection camera and radiation monitor immediately in a stand-alone mode, it also increases the cost and difficulty of integrating disparate commercial systems.

- The deployment took place in a larger enforcement context that has up to now emphasized and rewarded inspectors for the numbers of inspections they complete, not necessarily for achieving high rates of OOS orders. Thus the purpose of the ISSES (to help inspectors focus on the trucks with the worst safety records, and in effect drive upward the rate of OOS orders) is not directly aligned with the traditional goals of the inspectors in Kentucky. This institutional disconnect affected the degree to which the inspectors perceived the ISSES as helping them achieve their personal and organizational job goals.

- Lack of training was seen as another obstacle to more effective use of the ISSES. One KVE officer said, "It is a good system but there is no one sitting over the monitors watching the results."

System Performance Conclusions

- The radiation monitor appears to alert inspectors to potential radiation hazards. No attempt was made to simulate radiation-emitting loads to formally test the rates of false positive alarms or false negative (missed detection) alarms. A tendency for nuisance gamma alarms caused by naturally occurring substances, however, has the effect of making inspectors more likely to ignore all of the gamma radiation monitor alarms. As a rule, the KVE inspectors do attend to neutron alarms, which sound different in the scale house and are much fewer in number than the gamma alarms. An isotope identification capability recently deployed at the two newer ISSES stations (Kenton and Simpson) has also reduced the number of nuisance alarms. Data are being collected to develop computer-based "risk matrices" to further limit the number of nuisance radiological alarms in the future.

- The thermal inspection device enables inspectors to see potential heat-related defective or malfunctioning equipment that might be missed in a visual review, and archives video data for follow-up review. The effectiveness of the thermal inspection system appears to vary depending on the training, experience, and skills of the operator, especially in synchronizing the views of the ground-level IR/color camera and the gable-mounted color overview camera.

- The laser scanner appears to log every truck passing through the ISSES apparatus, but its adjustment is such that the system generates a certain number of extra (blank) records or extra trigger events, which is an impediment to later review of traffic data. For the sample of data reviewed for this evaluation, some gaps in the time synchronization were noted.

- The ISSES appears to perform with a minimum of unscheduled downtime. Partly owing to the exposed geographic location of the Laurel County weigh station, the hardware has been subject to several outages caused by lightning strikes and other power drops or interruptions. The system has experienced a low rate of hardware failure, other than some events related to the reliability of electrical power to the site.

- Based on experience at the first (Laurel) ISSES site, the location of the visible lighting fixtures was changed from the passenger side to the driver's side at Kenton to reduce the amount of stray light reaching the mainline of traffic. Also, the Kenton ISSES equipment was positioned approximately twice as far upstream from the scale house as the ISSES equipment at Laurel, in principle allowing Kenton inspectors more time to make decisions based on the system's output.

- As of mid-2007, the system appeared to be at a late stage in the product development cycle, not completely in full-scale production mode, but well beyond the field test prototype stage. It was not yet integrated with any current or historical state or national databases, which affected its usefulness for real-time enforcement applications, but it appeared to be functioning well in stand-alone mode.

Inspection Efficiency Conclusions

- A series of scenarios was constructed to compare Kentucky's current inspection selection methods with various progressive options for integrating ISSES and similar CVISN screening technologies at the state's weigh stations. The scenarios also explored variations in the inspection selection criteria that states could use in trying to focus their finite resources on the highest-risk carriers, vehicles, and drivers. Substantial potential reductions in crashes, injuries, and fatalities were predicted from wider deployment of ISSES. Estimates were made using statistical modeling.

- The roadside enforcement (RE) scenarios were defined as follows:
  - RE-0: Random Selection
  - RE-1: Baseline—Pre-ISSES/CVISN
  - RE-2: Mainline Electronic Screening based on ISS Score
  - RE-3: Electronic Screening based on Kentucky OOS Rate Inspection Selection Algorithm
  - RE-4: Electronic Screening based on high vehicle and/or driver OOS rates
  - RE-5: Electronic screening based on high driver OOS or brake violation rates
  - RE-6: Electronic screening based on IR screening and high driver OOS violation rate.

- According to the model, current roadside enforcement strategies (RE-1) are responsible for avoiding 126 truck-related crashes, which represents about 4.4 percent of the 2,853 crashes in Kentucky that occur annually, based on 2005 crash statistics. Furthermore, it is estimated that current roadside enforcement activities are responsible for preventing 33 injuries and 2 deaths.

- The safety benefits realized increases with each scenario RE-2 through RE-6. The maximum benefit is achieved with RE-6, where 755 crashes (629 more than in the baseline scenario) are avoided if the top 5 percent of vehicles in terms of driver OOS violations are inspected in conjunction with IR screening. This implies that about 26 percent of Kentucky's 2,853 annual truck-related crashes could be avoided under RE-6. In reality, this figure is an overestimate, because national crash rates were used in the safety benefit calculations, in turn because reliable crash rates for Kentucky were not available.

- In terms of injuries and fatalities, the incremental benefits range from 16 to 163 fewer injuries per year, and up to 7 fewer fatalities per year.

- To put the crash avoidance numbers into context, consider that the number of large trucks involved in crashes in Kentucky (2,853) is low relative to the 441,000 large trucks involved in crashes nationally, representing only 0.6 percent of national crashes. Also, the percent of Kentucky crashes relative to the number of inspections performed in Kentucky is about 3.3 percent. Comparatively, the national rate of crashes relative to the number of inspections is about 16 percent. Therefore, relative to the number of inspections, Kentucky's crash rate is smaller than the national crash rate. The exact reason for this is unknown, but possible explanations include a lower volume of traffic in Kentucky, less congested highways, or a smaller number of large cities.

- Recalculating the safety benefits achieved when the national number of vehicle and driver inspections in 2005 is used instead of Kentucky inspection figures finds that implementing scenario RE-6 avoids about 6.5 percent of all national crashes.

User Acceptance/Cost Conclusions

- As noted above, staffing and training were seen as main barriers to active use of ISSES in everyday KVE inspection operations. The majority of inspectors said ISSES appeared to be user-friendly, and that (compared to the training offered at the Laurel County site), more training is necessary to help them make full use of its capabilities.

- Respondents considered most ISSES radiation alarms to be caused by routine, naturally occurring substances (e.g., brick, porcelain, clay) or licensed, placarded medical products. Respondents indicated the radiation monitor needs to be fine-tuned to reduce nuisance alarms. After the time of the user acceptance interviews, the ISSES at the Laurel County site was adjusted to reduce the prevalence of nuisance alarms.

- Respondents indicated that they rely on the thermal imaging device with the greatest confidence because they can "actually see trucks on the screen" and believe it enables them to perform their job functions better. It appears to be easy to use, even given little training, and training could only help inspectors make better use of this subsystem.

- As for lessons learned from the Laurel County deployment, designers should carefully consider where equipment is sited before installation and obtain input from inspectors. As it is installed now, it appears that the equipment is located too far down the approach ramp from the mainline, at a point that is too close to the scale house. Inspectors need adequate time to interpret information from ISSES and then decide whether to stop a given vehicle.

- Deployment teams should provide equipment documentation and user guides along with contact information on-site (e.g., if a radiation alarm goes off) that affords inspectors access to personnel with a working knowledge of equipment. After the time of the user acceptance interviews, contact information for technical support was posted on the ISSES equipment at Laurel County.

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15. Supplementary Notes

Mr. Jeff Secrist (GTOM); Ms. Jane Lappin and Mr. John Augustine (COTRs)

16. Abstract

An advanced-technology Integrated Safety and Security Enforcement System (ISSES), now deployed at three commercial vehicle inspection sites along interstate highways in Kentucky, was evaluated from the point of view of system performance, potential effects on inspection selection efficiency (choosing the highest-risk trucks from the stream of commerce), user acceptance, and costs. Overall, the subsystems that were under evaluation in this task were found to be performing effectively in a stand-alone mode. The ISSES software and components now deployed, though operational, are considered to be in a development mode. The roadside system was not yet integrated with in-state or national databases of historical safety information on carriers or vehicles, so the ISSES was not able to provide instant, "actionable" historical information that the inspectors could apply in their decision-making. Kentucky's current inspection selection methods were compared with potential applications of ISSES technology across a set of scenarios, used to model improvements in commercial vehicle safety. Applying various combinations of inspection selection strategies and available or envisioned technologies for real-time vehicle identification and safety information exchange at the roadside, in a hypothetical statewide deployment supporting about 44,000 vehicle inspections and 86,000 driver inspections in a year, the ISSES was estimated to contribute to incremental reductions of between 63 and 629 commercial vehicle-related crashes per year, reductions of between 16 and 163 personal injuries, and reductions of up to 7 fatalities. Overall, to the extent that they had been exposed to the ISSES, the users were positive toward it and appeared to recognize its potential, but they regarded it as more of a developmental test or research device than as a tool that they wanted to use immediately in their day-to-day commercial vehicle inspection and law enforcement duties. Further information on the evaluation approach and methods is provided in a separate Technical Report (FHWA-JPO-08-025, EDL No. 14400).

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